Exploring the acquisition of verb inflections in Japanese: A probabilistic analysis of seven adult-child corpora

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Abstract:	The acquisition of verb form morphology is often studied using categorical criteria for determining the productivity of a morpheme. Applying this approach to Japanese, an agglutinative language, we find no consistent order for morpheme acquisition and productivity could be explained by sampling effects. To examine morpheme acquisition using more graded measures of productivity, we compared various regression models for predicting the age of acquisition of 311 verb forms across a large combined corpus of seven Japanese-speaking children (aged 1;1 to 5;1). Complex forms were learned earlier than frequency-matched simple forms and morpheme ending identity explained substantial variation. Both of these findings suggest that children have some segmented morphemes and learned some of their semantic/pragmatic characteristics. Sampling would predict that verb form acquisition would be sensitive to lemma and ending frequency, but acquisition was also sensitive to aspects of input frequency that were independent of these factors and this suggests that children are encoding whole verb forms in addition to creating forms with compositional morphological rules.

1. Introduction

How children learn the system of verb inflection in their language is a long-standing question in the field of language acquisition research (e.g. Berko, 1958; Brown, 1973; Cazden, 1968; Dressler, 2010; MacWhinney, 1978; Pinker, 1984; Pizzuto & Caselli, 1992; Shirai & Andersen, 1995; Slobin, 1985; Tomasello, 2000; Wexler, 1994; 1998). Research in this area has focused on a number of questions, including: When does knowledge of different verb inflections become productive? What factors determine the order of acquisition of different inflections? And to what extent is children's knowledge of verb inflection related to the frequency with which particular forms occur in the input? However, providing satisfactory answers to these questions is more difficult than it might at first appear, because it requires the researcher to solve a number of methodological problems relating to the questions of how to establish order of acquisition, how to operationalize predictors such as semantic and morphological complexity, and how to disentangle input frequency and sampling effects on age of acquisition.

With these challenges in mind, the aim of the present study is to investigate the acquisition of verb morphology in Japanese, a language with highly agglutinative verb morphology, in which all verb forms are marked with at least one suffix – but many are more complex, and are marked with a number of different suffixes. We first use type-based productivity measures to look at the earliest verb endings to emerge in

Japanese-speaking children's output and how consistent their pattern of emergence is across children. We then use an exploratory probabilistic approach to analyse naturalistic corpora of Japanese-speaking children and investigate some of the factors that might affect the age at which different inflected verb forms emerge in their speech, including morphological complexity, identity of ending, and the frequency of the lemma, the ending and the whole inflected verb form in the input.

1.1. Order of Acquisition

Since Brown's (1973) seminal study of 14 English morphemes, many researchers have sought to investigate the order in which different morphemes become productive in children's speech, and to do so across a range of different languages (see Chapters in Slobin, 1985 for examples). Brown's study did not focus specifically on verb morphology, but it did appear to show a relatively consistent order of acquisition across the 14 morphemes studied (though this conclusion has been qualified to some extent by subsequent research, e.g. de Villiers, & de Villiers, 1973; James & Khan, 1982).

Central to Brown's approach was the use of the 90% obligatory context criterion, according to which a morpheme was only considered acquired if it appeared in 90% of the contexts in which it was required in 3 consecutive recordings. The great strength of this criterion is that, by focusing on the percentage of obligatory contexts filled, it controls for the number of opportunities that the researcher has to observe the use of a

particular morpheme in the child's speech. However, an obvious limitation is that the 90% cut-off means that it is effectively a measure of mastery rather than a measure of productivity. This limitation has led many researchers to develop much less conservative criteria for attributing productive knowledge of verb morphology to the child. For example, some generativist researchers (e.g., Wexler, 1998) argue, on the basis of the low rates of errors of commission in children's speech, that children's use of verb morphology is productive from the earliest observable stages – and hence effectively adopt a first use productivity criterion. On the other hand, other researchers, who are more sensitive to the possibility that children's early use of morphology might be embedded in unanalyzed forms, argue for type-based criteria that attribute productivity on the basis that the child has been observed to use a particular morpheme with some criterial number of different verbs (and in some cases the relevant verbs with some criterial number of different morphemes). For example, in their work on Romance languages, a number of investigators (e.g., Fernández Martínez, 1994; Gathercole, Sebastián & Soto, 1999; Pizzuto & Caselli, 1992) attribute productive knowledge of verb inflections on the basis that the relevant inflection had been used with at least two different verbs and the relevant verbs with at least two different inflections; in her work on Korean, Choi (1991) attributes productive knowledge of modal suffixes on the basis that the relevant suffix had been produced with more than three different verbs; and in their work on Japanese, Otomo, Miyata and Shirai (2015) attribute knowledge of verb inflections on the basis that the child had produced the relevant suffix on at least 4

different verbs. These kinds of type-based measures have the advantage that they can, in principle, be used from early in development to distinguish between morphemes that are being used productively by the child and morphemes that have been learned as part of unanalysed verb forms. They also have the advantage that they can be used to investigate morphological development in languages like Japanese in which the high rate of argument omission makes it difficult to identify obligatory contexts. However, since they do not control for the number of opportunities that the researcher has to observe the relevant morpheme, they are likely to be sensitive to sampling effects (Tomasello & Stahl, 2004; Yang, 2013). That is to say, morphemes that occur more frequently in the language are likely to reach criterion earlier than morphemes that occur less frequently in the language, simply because they are more likely to be sampled. This may be a particular problem when attempting to use first use and type-based measures to estimate the order of emergence of morphemes that occur with very different frequencies in the language.

In the light of this problem, the first part of this study uses type-based productivity measures to look at the earliest forms to reach criteria in Japanese-speaking children's output, and investigates whether these criteria can reliably estimate the order in which Japanese inflections become productive. This allows us not only to identify any commonalities in the order of emergence of inflections across children, but also to

reveal how order of emergence is affected by the use of different criteria, and the extent to which different criteria of emergence are sensitive to sampling effects.

1.2. Factors affecting order of acquisition

Research on potential factors affecting the order of acquisition of inflectional morphology in children's speech also has a long history in language acquisition research. For example, both Brown (1973) and de Villiers and de Villiers (1973) considered the extent to which the order of acquisition revealed in their analyses could be explained in terms of input frequency and semantic and grammatical complexity. They both concluded that, while the frequency of morphemes in parental speech did not predict order of acquisition, semantic and grammatical complexity did appear to play a role, though, without a strong means of operationalizing semantic or grammatical complexity a priori, it was difficult to determine the precise role of either of these predictors.

However, an obvious problem with these early studies is that their conclusions relate to the order in which the morphemes in question reached Brown's very stringent acquisition criterion (as opposed to the order in which they became productive). They are also based on a very heterogeneous set of morphemes and a relatively crude measure of input frequency (i.e. the number of tokens of the morpheme in the input as opposed to the number of different nouns or verbs that were marked with the relevant

morpheme). All of these factors are likely to militate against finding a relation between input frequency and order of acquisition. More recent research has tended to distinguish between noun and verb morphology and to reveal frequency effects at a number of different levels. For example, Bybee (1995) discusses the interplay between type and token frequency in determining the productivity of inflection across a number of different systems and languages; Matthews and Theakston (2006) report frequency effects on children's tendency to use both plural *–s* and past tense *–ed* correctly; and Räsänen, Ambridge and Pine (2014) report effects of the relative frequency with which verbs occur as third person singular versus bare stem forms on the rate at which children produce third person singular forms in obligatory contexts in English (see Ambridge, Rowland, Theakston & Kidd, 2015 for a review). While these effects are open to a variety of possible interpretations, they suggest that there may be a stronger relation between input frequency and the acquisition of inflectional morphology, in general, and between input frequency and the acquisition of verb morphology, in particular, than was assumed in Brown and de Villiers and de Villiers' early studies.

With respect to the issue of morphological complexity, cross-linguistic analyses have shed further light on what might be considered morphologically complex from the child's point of view. For example, it has been argued that children find it easier to learn inflections that are morphologically transparent in the sense that they are attached to the stem without altering its phonological form (e.g. Clark, Frant Hecht & Mulford, 1986;

Dressler, 2010; Peters & Menn, 1993), and that children find it easier to learn inflections that are morphologically simple in the sense that they exhibit a one-to-one correspondence between meaning and form (e.g. Slobin, 1985; Dressler, 2005; 2010). This kind of morphological simplicity has also been assumed to provide an explanation for why agglutinative systems in which each inflection expresses only one grammatical distinction tend to be learned earlier than fusional systems in which inflections often express several grammatical distinctions at once (e.g. Aksu-Koç & Slobin, 1985; Dressler, 2010). However, it is still unclear how children acquire forms that are complex by virtue of the number of inflectional morphemes that they include. That is to say, it is not clear whether children learn agglutinative verb morphology by learning complex forms as unanalysed wholes and only subsequently identifying the relation between the component inflections and the distinctions that they encode (e.g., Mithun, 1989), or whether children start by learning simple forms to which they add morphemes as they identify the distinctions that these additional morphemes encode in the input (e.g., Iwatate, 1981; Takanashi, 2009).

In view of these questions about the role of frequency and complexity, the aim of the second part of this study is to investigate the relative importance of these factors in determining the age of acquisition of inflected verb forms in Japanese. Since it is difficult to establish the age at which particular morphemes become productive in children's speech, we adopt a data-driven approach to this issue and use regression analyses to

explore the extent to which it is possible to predict the average age of acquisition of particular inflected verb forms in terms of 1) the morphological complexity of those verb forms as measured by the number of morphemes in the endings, 2) the ending identity, and 3) the frequency with which those inflected verb forms, and their lemmas and endings occur in the input language.

1.3. De-confounding frequency and sampling effects on age of acquisition

There is now considerable evidence that the frequency with which particular words and sequences occur in the input plays an important role in determining the age at which these forms are acquired by the child (e.g. Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Naigles & Hoff-Ginsberg, 1998: Rowland, Pine, Lieven & Theakston, 2003; Theakston, Lieven, Pine & Rowland, 2004). However, much of this evidence is based on naturalistic samples and is therefore subject to the potential criticism that age of acquisition is confounded with sampling effects. This is because, as Tomasello and Stahl (2004) point out, although the frequency with which forms occur in the language is likely to affect the rate at which they are learned, it is also likely to affect the probability that they will be observed in any given speech sample, with the result that high frequency forms are likely to be observed earlier than low frequency forms even if they were actually acquired at the same point in time (see Yang, 2013 for a related argument).

In view of this problem, we also investigate the extent to which it is possible to establish a relation between the age of acquisition of particular inflected verb forms in Japanese and the frequency with which those forms occur in the input, even after controlling for sampling effects in naturalistic speech. This will be done by using regression techniques to look for an effect of form frequency on age of acquisition while controlling for the likelihood that a particular form will occur in the language as indexed by the combined frequency of the lemmas and endings included in the form.

1.4. Inflectional verb morphology in Japanese

The present study focuses on Japanese because its agglutinative verb morphology means that it is well suited to investigating the issues identified above. Japanese has a relatively rich system of verb inflection in which a number of distinctions, including tense, aspect, voice, polarity and politeness are expressed by means of suffixation on verb stems. In contrast to languages with fusional verb morphology, like English, Japanese verb morphology is highly agglutinative. Thus, according to Shibatani (1990: 221) Japanese inflectional endings "are fairly clearly segmentable, and the segmented endings (or suffixes) are correlated with inflectional categories in a one-to-one fashion". The simplest finite verb forms consist of a verb stem with a tense-marking suffix (NONPAST or PAST), as in *tabe-ru* eat-NONPAST 'eat' and *tabe-ta* eat-PAST 'ate'. However, because Japanese verb morphology is highly

agglutinative, more complex verb forms are also relatively frequent. These consist of a verb stem with further suffixes attached between the stem and the final tense-marking suffix (e.g., *tabe-sase-ta* eat-CAUSATIVE-PAST 'forced to eat', *tabe-sase-rare-ta* eat-CAUSATIVE-PASSIVE-PAST 'was forced to eat'). In this paper, the term 'ending' is used to refer to the verb inflection that follows a verb stem regardless of its semantic or functional properties, or whether it consists of a single suffix or a combination of suffixes.

Previous work on the acquisition of verb inflection in Japanese has identified a number of endings that appear early in children's speech. For example, Clancy (1985) lists all of the following as early-acquired morphemes or morpheme combinations: -*te* imperative, -*ta* past, -*teru* progressive/resultative nonpast, -*ru* nonpast, -*chatta* completive past, -*nai* negative nonpast, -*tai* desiderative nonpast (labels are modified by the current authors for consistency). Although the productivity of these endings is difficult to determine, children's early use of these endings appears to be largely error-free (Clancy, 1985; Kato, Sato, Chikuda, Miyoshi, Sakai, & Koizumi, 2003), and Tanoue (1981) claims that at least some of them are used productively before the child reaches an MLU of 1.5, which is considerably earlier than in English, where verb morphology is rare before the child reaches an MLU of 2.0.

With regard to order of acquisition, Otomo, Miyata and Shirai (2015) found that the order in which Japanese verb inflections become productive was relatively

consistent across the four children in their corpus study. This study used a type-based frequency criterion according to which the point at which the child had been observed to produce the target inflection with 4 different verbs was regarded as the point of onset of productive knowledge. Otomo et al. found high correlations between order of acquisition and type and token frequency in child-directed speech and argued that order of acquisition is determined by the frequency with which different morphemes occur in the input. However, they also discuss semantic and morphological complexity as potentially important factors. On the other hand, studies that have focused specifically on the way in which complex forms are acquired have tended to downplay the role of input frequency. For example, in another corpus-based study, Iwatate (1981) interprets the data on order of acquisition as providing support for the idea that complex inflectional forms are learned by attaching morphemes to already acquired simple forms, and in a study of children's use of the high frequency verbs 'go' and 'come', Takanashi (2009) argues that there is a common order in the acquisition of verb inflections, and that this order is not determined by input frequency, but by the tendency for children to learn simple forms early and more complex forms later.

To summarise, although the previous literature suggests that Japanese-speaking children have at least some productive knowledge of verb inflection relatively early, it is much less clear whether the order in which particular endings are acquired is consistent across children, or how age of acquisition is affected by input frequency and

morphological complexity. It is also unclear whether children's knowledge of multi-morphemic endings is fully compositional during the early stages, or reflects the learning of such endings as inflections that fuse multiple adult morphemes into a single form. The aim of the present study is to clarify these issues with a view to increasing our understanding of the way in which complex inflectional morphology, in general, and Japanese verb morphology, in particular, are acquired.

2. Two corpus-based approaches for examining the acquisition of Japanese verb morphology

The present paper reports two different sets of analyses that correspond to different research questions. The first of these is a set of descriptive and correlational analyses of the earliest endings to occur in Japanese children's output. These correlational analyses allow us to better understand how type-based criteria are related to the order of acquisition of inflectional endings in children's acquisition of Japanese verbs. Specifically, we identify the first 10 verb endings to become productive in the speech of three children according to three different productivity criteria (*First use*, *Use with 5 different verb types* and *Use with 10 different verb types*), and ask three questions: 1) Which are the first endings to emerge – and do they include multi-morphemic endings? 2) How consistent is the pattern of emergence across different children – and how is it affected by the use of different productivity criteria? and 3) How

sensitive are the different productivity criteria to sampling effects – and hence how seriously should we take the resulting type-based productivity measures?

The second part is a set of multiple regression analyses using a probabilistic measure of age of acquisition of inflected verb forms from a composite dataset of seven children's corpora. We explore the acquisition of verb inflections not by applying a specific productivity criterion, which has been typical in previous studies on the age of acquisition of verb endings, but by building a series of regression models. These models investigate the effect of morphological complexity, inflectional category, and frequency on verb form Age of Acquisition (AoA), which is calculated on the basis of the ages of the first 30 uses of the inflected verb form in the corpora. We also take sampling effects into consideration by introducing a residualized frequency measure where sampling likelihood of the form has been factored out. The exploratory quantitative approach adopted in these analyses allows us not only to better understand the complex process of verb acquisition but also to refine our characterization of the productivity and compositionality of children's verb morphology.

2.1 Corpora

The corpora used in the study were the seven Japanese corpora available in the CHILDES database (MacWhinney, 2000) which have morphological codings. These are the corpora of three children (Aki, Ryo and Tai) that make up the Miyata corpus (Miyata,

2004a; 2004b; 2004c) and four children (ArikaM, Asato, Nanami, Tomito) that make up the MiiPro corpus (Miyata & Nisisawa, 2009; 2010; Nisisawa & Miyata, 2009; 2010). The details of these corpora are provided in Table 1. The corpora that we used involved mothers interacting with their children, so we computed input frequency measures for all of the analyses based on the mother's input to avoid any ungrammatical forms produced by other children. We used the LuCiD toolkit version of the CHILDES corpora, where each word in each utterance was paired with the age of the target child in months when it was produced (Chang, 2017).

Table 1. Details of the corpus data used in this study

Corpus	Child	Child's age (in months)	Number of verbs in child's speech	Number of verbs in mother's
Miyata	Aki	17.2-36.0	4573	11311
Miyata	Ryo	16.1-37.0	3630	3522
Miyata	Tai	17.6-.37.9	11457	18634
MiiPro	ArikaM	36.1-61.3	21328	17566
MiiPro	Nanami	13.9-60.5	8536	25638

MiiPro	Asato	13.9-60.9	8145	25666
MiiPro	Tomito	35.9-61.7	4368	12041

3. Study 1. Descriptive and correlational analysis using type-based criteria

This first study was a descriptive study of children's first endings which used correlational analyses of age of acquisition using type-based productivity criteria in order to look at how well the use of these criteria works for determining the order of acquisition of grammatical morphemes in children's acquisition of Japanese verbs.

3.1 Methodology

Since this study focused on the earliest endings to occur in Japanese children's speech, analysis was only conducted on the corpora of Aki, Nanami and Ryo – as these are the only three corpora that include recordings of the very earliest stages of verb use. We selected the first 10 endings to become productive in the speech of these three children according to 3 different productivity criteria. The first criterion was *first use* (i.e. the use of the ending with a single verb lemma). The second was *use with 5 different verb lemmas*, and the third was *use with 10 different verb lemmas*. This analysis involved excluding all error-coded utterances, extracting all the children's verb forms

from the morphologically-coded utterances, and then determining the order in which each of the endings produced by the child reached each of the three productivity criteria. Since we were interested in whether the children produced verbs with multi-morphemic endings, endings were defined as the part of the verb form that follows the verb stem, which can be a single suffix (e.g. PAST) or a suffix-combination (e.g. COMPLETIVE-PAST, see Table 2 for examples of some of the endings in our corpus). In order to assess how sensitive the different productivity criteria were to sampling effects, we correlated the age at which each ending reached criterion for each child with the frequency of that ending in the child's speech.

Table 2. Examples of verb forms with different endings using verb stem *tabe* "eat"

Ending	Number of morphemes	Verb form	Gloss
NONPAST	1	tabe-ru	eat
PAST	1	tabe-ta	Ate
IMPERATIVE (-te)	1	tabe-te	Eat! (command)

CONNECTIVE	1	tabe-te	eat and (followed by another predicate or clause)
HORTATIVE	1	tabe-yoo	let's eat!
CONDITIONAL (-tara)	1	tabe-tara	if X eat
CONDITIONAL (-ba)	1	tabe-reba	if X eat
NEGATIVE-NONPAST	2	tabe-na-i	do not eat
NEGATIVE-PAST	2	tabe-na-katta	did not eat
STATIVE-NONPAST	2	tabe-te-ru	be eating
STATIVE-PAST	2	tabe-te-ta	was eating
COMPLETIVE-NONPAST	2	tabe-cha-u	will have eaten/ will end up eating
COMPLETIVE-PAST	2	tabe-chat-ta	have eaten/ ended up eating
POTENTIAL-NONPAST	2	tabe-(ra)re-ru	can eat
POTENTIAL-PAST	2	tabe-(ra)re-ta	could eat

POLITE-NONPAST	2	tabe-mas-u	eat (polite)
POLITE-PAST	2	tabe-masi-ta	ate (polite)
DESIDERATIVE-NONPAST	2	tabe-ta-i	want to eat
POTENTIAL-NEGATIVE-NONPAST	3	tabe-(ra)re-na-i	cannot eat
STATIVE-NEGATIVE-NONPAST	3	tabe-te-na-i	be not eating

3.2 What is the order of acquisition by type-based criteria?

The first issue that we examined was the nature of the first 10 endings to emerge using different productivity criteria and whether multi-morphemic endings were present in this set. Tables 3-5 show the first 10 endings to become productive in the three children according to the three different productivity criteria (Use with 1, 5 and 10 verb lemma types). It can be seen from these tables that the first endings to emerge contain a mixture of simple and complex endings, with multi-morphemic endings making up at least half of the endings for all three children, irrespective of criterion, and the COMPLETIVE-PAST and NEGATIVE-NONPAST among the first to reach the most conservative type-based criteria for all three children. This pattern of emergence would

seem to count against the idea that complex forms emerge later than simple forms (e.g. Bassano, 2000; Iwatate, 1981; Takanashi, 2009), and is consistent with the idea that complex endings can be acquired early provided they are sufficiently frequent in the input (Tatsumi, Ambridge & Pine, 2018).

Table 3. Order of emergence of endings in three children's data by 1-type criterion

	Aki		Nanami		Ryo	
	Ending	Age in months	Ending	Age in months	Ending	Age in months
1	PAST	20.7	NONPAST	14.8	NEGATIVE-NONPAST	16.6
2	NONPAST	20.7	IMPERATIVE (-te)	15.7	PAST	22.8
3	NEGATIVE-NONPAST	23.9	PAST	16.7	COMPLETIVE-PAST	23.0

4	IMPERATIVE (-te)	24.2	NEGATIVE-NONPAST	19.0	IMPERATIVE (-te)	23.3
5	COMPLETIVE-PAST	25.3	HORTATIVE	19.0	POTENTIAL-PAST	23.6
6	CONNECTIVE	25.3	STATIVE-NONPAST	21.9	NONPAST	23.9
7	STATIVE-IMPERATIVE (-te)	25.5	STATIVE-PAST	21.9	POTENTIAL-NEGATIVE-NONPAST	24.5
8	POTENTIAL-PAST	26.7	COMPLETIVE-PAST	21.9	CONNECTIVE	24.5
9	HORTATIVE	26.4	GERUND	21.9	STATIVE-NEGATIVE-NONPAST	24.5

10	COMPLETIVE -NONPAST	26.7	COMPLETIVE-NONPAST	22.4	POLITE-NEGATIVE (n) -NONPAST	24.9

Table 4. Order of emergence of endings in three children's data by 5-type criterion

	Aki		Nanami		Ryo	
	Ending	Age in months	Ending	Age in months	Ending	Age in months
1	PAST	25.3	PAST	19.0	IMPERATIVE (-te)	23.9
2	IMPERATIVE (-te)	26.0	NONPAST	20.5	PAST	24.3
3	NONPAST	26.5	IMPERATIVE (-te)	21.9	COMPLETIVE-PAST	24.3

4	NEGATIVE-NONPAST	27.4	CONNECTIVE	22.4	NEGATIVE-NONPAST	24.5
5	CONNECTIVE	27.8	NEGATIVE-NONPAST	22.8	NONPAST	25.1
6	STATIVE-NONPAST	28.1	STATIVE-NONPAST	23.3	STATIVE-NEGATIVE-NONPAST	25.8
7	HORTATIVE	28.1	STATIVE-IMPERATIVE (-te)	26.4	STATIVE-NONPAST	26.5
8	COMPLETIVE-NONPAST	29.2	HORTATIVE	26.4	CONNECTIVE	27.5
9	STATIVE-PAST	29.2	COMPLETIVE-PAST	27.1	STATIVE-PAST	27.5

10	COMPLETIVE -PAST	29.2	STATIVE-NEGATIVE-NONPAST	27.6	POTENTIAL-NEGATIVE-NONPAST	27.6

Table 5. Order of emergence of endings in three children's data by 10-type criterion

	Aki		Nanami		Ryo	
	Ending	Age in months	Ending	Age in months	Ending	Age in months
1	PAST	26.0	PAST	21.9	PAST	24.8
2	IMPERATIVE (-te)	27.1	NONPAST	22.4	NONPAST	25.4
3	NONPAST	27.4	CONNECTIVE	23.3	NEGATIVE-NONPAST	25.6
4	STATIVE-NONPAST	29.2	IMPERATIVE (-te)	23.3	COMPLETIVE-PAST	25.6

5	CONNECTIVE	29.2	STATIVE-NONPAST	26.4	IMPERATIVE (-te)	25.8
6	HORTATIVE	29.4	NEGATIVE-NONPAST	27.6	STATIVE-NEGATIVE-NONPAST	27.6
7	COMPLETIVE-NONPAST	30.5	HORTATIVE	27.6	CONNECTIVE	27.6
8	NEGATIVE-NONPAST	30.5	STATIVE-NEGATIVE-NONPAST	28.6	STATIVE-NONPAST	28.7
9	COMPLETIVE-PAST	30.9	STATIVE-PAST	28.6	STATIVE-PAST	30.2
10	STATIVE-PAST	30.9	COMPLETIVE-PAST	30.3	COMPLETIVE-NONPAST	33.8

Whether it is possible to make claims about morphological processing in acquisition depends on there being consistent patterns of emergence across children and across different productivity criteria. To examine this issue, we analysed the consistency of the patterns across children. There is substantial overlap across children in the identity of the first 10 endings, with 6 endings (COMPLETIVE-PAST, CONNECTIVE, IMPERATIVE (-te), NEGATIVE-NONPAST, NONPAST, PAST; Table 3-5) among the first 10 to emerge for all three children, irrespective of criterion, and a further two endings (STATIVE-PAST and STATIVE-NONPAST) among the first 10 to reach the most conservative productivity criterion. These data suggest a relatively consistent pattern of emergence across children, with this pattern tending to increase in consistency as the productivity criterion becomes more conservative. However, it is also clear that even the most conservative criterion does not allow us to identify a consistent order of emergence.

Another issue is that the order of acquisition may not be due to the way in which endings are acquired by the children, but instead to the way that their data is sampled. In order to assess how sensitive the different productivity criteria were to sampling effects, we correlated the age at which each ending reached criterion for each child with the frequency of that ending in the child's speech. We computed the Pearson product moment correlation with a t-test. The results of this analysis are presented in Table 6 and show a consistent pattern of moderate to high negative correlations between the

age at which the different endings reached criterion and the frequency with which they occurred in the children's speech, with the correlations increasing in size as the productivity criterion becomes stricter. These results suggest that the kind of type-based productivity measures used here and in previous research are highly sensitive to sampling effects, and hence that conclusions based on such measures need to be treated with some caution.

Table 6. Correlations between age at which productivity criterion was reached and frequency in the individual child's speech (different correlations are based on different numbers of data points depending on the number of endings reaching criterion in each child's speech)

Criterion	Child	r	df	p
1	Aki	-0.671	43	<.001
5	Aki	-0.659	17	0.002
10	Aki	-0.692	13	0.004
1	Nanami	-0.443	108	<.001
5	Nanami	-0.561	34	<.001
10	Nanami	-0.596	24	0.001

1	Ryo	-0.589	41	<.001
5	Ryo	-0.694	14	0.003
10	Ryo	-0.759	12	0.002

When taken as a whole, these results suggest that, although Japanese-speaking children do use complex forms with some degree of productivity from early in development, and that this pattern is relatively consistent across children, type-based productivity measures do not provide us with a reliable means of estimating when particular endings become productive, or of measuring differences in productivity across different endings. The implication is that, if we are interested in understanding the factors that affect the way in which different endings are acquired, we need to use a more sophisticated quantitative approach.

4. Study 2 Exploratory analyses using *verb form* AoA

In the previous descriptive analysis, age of acquisition was computed with respect to particular children. While we found some consistent patterns for frequent endings, this approach was limited to verb forms that are sampled for each child and there was variability in the lemmas and endings that were used by each child. To better understand how various factors influence the acquisition of morphology, we combined

the data from all seven CHILDES corpora (see Section 2.1) and treated them as a single longitudinal corpus of an idealized Japanese child. Instead of studying the emergence of verb endings such as -*ta* PAST as in the previous analysis, we computed *verb form* AoA (i.e., the age of acquisition of whole verb forms such as *tabe-ta* eat-PAST), which was the mean age in months at which the first 30 instances of this verb form appeared in the seven-child corpus. By requiring 30 instances, we aimed to ensure that our measure of verb form AoA would not be strongly affected by a few uses early in development, but would instead reflect the time in development when that verb is consistently used. This approach also removes any infrequent verb forms, which might show unstable behavior. The final average verb form AoA dataset consists of 311 different verb forms with 89 different lemmas and 27 different endings, which provides a reasonably large sample of verb forms for analysis.

In this larger dataset, we examined four issues using regression models that predicted verb form AoA (Table 7). Since previous studies have found inconsistent results on the relationship between AoA and morphological complexity (e.g., Mithun, 1989; Iwatate 1991), the first model examined whether the number of morphemes were related to verb form AoA. As some studies have argued that particular endings are easier than others in Japanese (e.g., Clancy, 1985; Otomo et al. (2015), the second model tested whether endings could predict AoA. Children are not born knowing Japanese verb endings, so AoA may reflect the frequency of forms in the input and

hence the third model tested whether lemma and ending frequency could predict AoA. Finally, it is possible that frequency effects arise from sampling issues and hence a fourth model examined whether frequency matters when sampling effects are factored out. These analyses were performed as separate regression models, because these models ask different questions related to these datasets. Also, there are strong correlations between some of these independent variables and therefore we could not include them in the same model (e.g., there is only one ending frequency for each ending identity, so it is not possible to include both in the same model).

Table 7. List of multiple regression models and corresponding research questions in this section

	DV and IVs	research question
1	verb form AoA ~ input frequency * morphological complexity	Does morphological complexity predict late AoA?
2	verb form AoA ~ input frequency * ending category	Does AoA change depending on the identity of ending?

3	verb form AoA ~ input lemma frequency * input ending frequency	Is AoA sensitive to lemma and ending frequency?
4	verb form AoA ~ input lemma frequency + input ending frequency + input lemma frequency : input ending frequency + residualised input frequency	Is the effect of input frequency real (even after controlling for sampling effect)?

4.1 Methodology

As described above, verb form AoA was computed for verb forms that occurred more then 30 times across the seven corpora. Input frequency of verb forms, lemmas, and endings was computed based on the mother's child-directed speech from the combined corpus. Some frequency measures were skewed due to Zipfian effects, and this means that the effect of these variables could be driven by a few highly frequent items. To make the effect of these variables more distributed across all of the items, frequency measures that were skewed were log-transformed (verb form frequency and lemma frequency were log-transformed). All frequency measures were centred. Normal-Q-Q plots revealed some non-normality of residuals for some of the models, but this non-normality was removed when AoA was log transformed. All regression analyses were

conducted in R (R Core Team, 2015), and the significance of each main effect and interaction was tested by model comparison.

One potential problem with the verb form AoA measure is that early AoA scores may be driven by individual children, rather than being representative of a larger number of children. Gries (forthcoming) discusses how dispersion (how evenly distributed a target form is across different parts of a corpus) can affect the validity of frequency-based assumptions in psycholinguistic research. To examine whether this was a problem in our dataset, we counted how many children used each verb form (lemma + morphology) and then calculated the average number of children for each lemma across different AoAs (Figure 1). The figure shows that earlier forms are shared by more speakers than later forms. This is because earlier lemmas are frequent forms that are shared by many speakers, while later forms are less frequent and more child-specific. It also shows that, for all of the lemmas, at least one form of the lemma was used by two speakers, as the mean use for each lemma is above one. The implication is that, despite some variability, the verb form AoA is not seriously affected by dispersion and seems to be an appropriate way to represent the general pattern of emergence of verb forms in children.

[Insert Figure 1 here]

4.2 Does morphological complexity predict late AoA?

As mentioned earlier, researchers have argued that morphological complexity influences verb form acquisition (Slobin, 1985). While children do not know how many morphemes are present in a form before acquiring it, complex forms are longer, less frequent, have more form-meaning mappings, and more specific pragmatic constraints. Japanese researchers have argued that simple forms are learned before complex forms (Takanashi, 2009; Iwatate, 1981). To examine this issue, a regression model was used to predict log verb form AoA based on log input frequency of the inflected verb form and morphological complexity as predictors (Table 8). Morphological complexity was coded as a numeric value: number of morphemes with 1 subtracted in order to make the intercept and beta of input frequency reflect the results of the simple 1-morpheme endings. This model explained 35% of the variance and revealed a significant negative main effect of log input frequency such that children tended to acquire simple forms with high input frequency early (β =-0.113, SE=0.009, F(1,307)= 156.785, p<.001). There was also a significant negative main effect of morphological complexity such that children tended to acquire complex forms earlier than simple forms (β =-0.049, SE=0.018, F(1,307) = 8.697, p<.01). However, there was no evidence for an interaction between input frequency and complexity (p>.5). Figure 2 suggests that both frequency and complexity play a role in explaining verb form AoA. The lack of an interaction with

frequency implies that this morpheme complexity effect is not due to differences in frequency for items with different numbers of morphemes, but rather to some factor that is independent of frequency (e.g., complexity, semantics, pragmatic salience).

[Insert Figure 2 here]

Table 8. Model summary for log verb form AoA by log input frequency of the inflected verb form and morphological complexity (i.e. the number of morphemes in the ending)

	Estimate	Std. Error	F value	p
Log input frequency	-0.113	0.009	156.785	< .001 ***
morphological complexity	-0.049	0.018	8.697	0.003 **
Interaction of log input frequency	0.011	0.020	0.307	0.580

and morphological complexity				

The finding that morphologically complex forms appear earlier is not compatible with previous studies that argue the complexity has a negative effect on learning (Anglin, 1993; Takanashi, 2009; Iwatate, 1981). It is also not obvious how to explain this in terms of frequency measures, because frequent endings should be learned earlier and simple endings like past tense have higher token and type frequency than complex endings. One possible explanation of these findings from a communicative perspective is that many of the morphologically complex forms that appear early may be particularly salient to the child for pragmatic reasons. For example, 6 out of the 7 forms with 3-morpheme endings have a POTENTIAL-NEGATIVE-NONPAST ending, which is often used by children when they are frustrated by their unsuccessful actions (e.g., *toorenai* "cannot go through", *hairenai* "cannot enter" and *torenai* "cannot take it"). A typical pragmatic function of these forms is to ask people around for help with these actions. Another example from verb forms with 2-morpheme endings is *kowarechatta* "it got broken", which has the same basic meaning as *kowareta* "it was broken", but the ending –*chat-ta* (COMPLETIVE-PAST) expresses the speaker's subjective negative attitude, such as shock or regret, about the event (Ono & Suzuki, 1993) and is common in child-directed speech as a way of socializing children (Suzuki, 1999). Thus, one reason why

complex forms may appear earlier than expected based on their input frequency is that these forms are used in emotionally salient situations by both parents and children. Even if not all complex forms are emotionally salient, it is clear that combined agglutinative morphemes tend to mark relatively specific meanings compared to single morphemes. In fact, specificity is a factor that is often discussed by researchers studying polysynthetic languages (e.g. Brown, 1998; Stoll et al., 2012), in which children tend to start with morphologically complex verbs with rich, lexically-detailed semantics as opposed to more abstract and general meanings.

We also need to take into consideration that our inclusion criteria allowed only a limited range of complex endings in the dataset. In fact, there were 7 forms with 3-morpheme ending forms, and 94 forms with 2-morpheme ending, which are much reduced compared to the number of simple verb forms (n=210 for 1-morpheme ending forms). Since verb forms with multi-morphemic endings tend to be low frequency, our criterion is likely to bias for those multi-morphemic forms that are used frequently, and it is likely that these forms will have strong motivations for their use (e.g., conveying emotion). In contrast, the forms with single-morpheme endings encode a heterogeneous set of meanings and this might be another reason why frequency-equivalent forms with single-morpheme endings were acquired later on average than forms with multi-morphemic endings.

Overall, it is clear from these results that morphological complexity does not predict late acquisition, which is in line with the findings in our earlier descriptive analysis. Children are able to use complex forms from early on when they are available and communicatively important. However, it is also clear from Figure 1 that there is a great deal of variability that is left unexplained either by the frequency of inflected verb forms or by their morphological complexity.

4.3 Does AoA change depending on the identity of ending?

One issue in morpheme acquisition is the question of whether children have actually segmented the ending from the lemma. To examine this question, we built a second model that included the identity of the endings. If children have only acquired whole forms, then ending identity will only be randomly associated with AoA. If they have segmented a few endings, then we would predict that this ending identity model would only explain a small amount of the variance in AoA. Since we need data for estimating each ending parameter, we restricted our analysis to the 10 endings that had more than 6 data points each (Figure 3). This means that these endings are relatively common since they are used in 6 different inflected forms, each of which appear more than 30 times in the dataset. A regression was used to predict log AoA with centered log input frequency of inflected verb forms crossed with categorically coded morphological endings. This model explained 52% of the variance, which is much greater than the

35% for the model with just morphological complexity. This analysis revealed a significant negative main effect of log input frequency (β =-0.076, SE=0.027, F(1,247)=201.742, p<.001), where high input frequency was associated with early acquisition. There was also a significant main effect of ending identity (F(9, 247)=11.038, p<.001), but no evidence of an interaction between log input frequency and ending identity (p>0.1). These results suggest that each ending is acquired according to a timetable that is not fully predicted by input frequency. For example, the verb forms with a COMPLETIVE-PAST ending are acquired earlier than forms with a POLITE-PAST ending (M=27.147 and 36.189 respectively, t(20)=3.286, p<.01). Some forms with a POLITE-PAST ending can be quite formulaic in usage such as *dekimashita* ("have made"), which is often used when a child is finished with something (e.g., finished painting, finished tidying up, etc.) and *tsukimashita* ("arrived"), which is often used when playing with trains. Another interesting example is the forms with an IMPERATIVE (-te) ending. For example, *doite* ("get out of my way") is a useful command that children can use to make people move. This is the earliest acquired imperative form despite its relatively low input frequency. The effect of ending identity in this analysis demonstrates that the emergence of these forms in acquisition is not just a result of their frequency in parental utterances, but also depends on the ending-specific semantics and communicative function.

[Insert Figure 3 here]

If children only used whole unsegmented forms, then ending identity would have a random relationship to verb form AoA. The fact that this model explains nearly half of the variability in AoA suggests that children have many segmented endings that drive their acquisition of verb forms. While this model provides evidence for segmentation of endings, it is not a realistic account of the knowledge that children use to acquire their language. This is because the model has perfect knowledge of the endings for every word in the language. On the other hand, children must infer knowledge of the endings based on factors like semantics and frequency and we explore whether this information can predict their production of verb forms in the next analysis.

4.4 Is AoA sensitive to lemma and ending frequencies?

One way that children can acquire endings is by repeatedly experiencing an ending across different tokens (e.g., tabe-ta, tabe-ta, tabe-ta), and this predicts that frequent endings should be easier to learn than rare endings. This suggests that the token frequency of an ending should predict age of acquisition. But it is also possible that children are sensitive to type frequency for each ending, which is the number of unique verb lemmas associated with each ending (e.g., tabe-ta, ne-ta, ochi-ta).

However, when we computed type frequency for our corpus, there was a correlation of 0.98 between ending type frequency and ending token frequency. This means that in this Japanese corpus, type and token frequency for verb endings are essentially the same and, due to the high correlation, it is inappropriate to include both in our model. Therefore, we built a third model to predict log verb form AoA with log lemma frequency (e.g. the input token frequency of lemma tabe 'eat' as in tabe-te-ta eat-STATIVE-PAST) crossed with ending frequency (e.g. the input token frequency of ending –te-ta STATIVE-PAST). Notice that we also cannot add ending identity to the model, as there is only one frequency for each ending identity and hence ending identity will explain all of the variance associated with ending frequency (when predicting ending frequency with identity, there is no residual variance). We found that children tended to learn forms with frequent lemmas early (β=-0.060, SE=-0.009, $F(1,307)=30.617$, $p<.001$), and tended to learn forms with frequent endings early (β= -0.000005, SE=0.000001, $F(1,307)=17.331$, $p<.001$), as summarized in Table 9. There was also an interaction between these two variables (β=-0.000005, SE=0.000001, $F(1,307)=29.187$, $p<.001$). This analysis suggests that children are encoding lemma and ending frequency and this is why AoA is sensitive to these factors. Since type and token frequency of endings are highly correlated in this data set, this study is consistent with the possibility that ending type frequency is also influencing children's acquisition of these forms. Another interesting point that arises from a comparison of this model and the previous model is that this model explains only 19% of the variance whereas the previous model with

ending identity explained 52%. This difference suggests that the effect of ending identity in the earlier model is not simply due to the input frequency of the ending.

Table 9. Model summary for log verb form AoA by log input frequency of the lemma and ending

	Estimate	Std. Error	F value	P
input frequency of lemma	-0.060	0.009	30.617	< .001***
input frequency of ending	-0.000005	0.000001	17.331	< .001 ***
input frequency of lemma : input frequency of ending	-0.000005	0.000001	29.187	< .001 ***

This analysis demonstrated that children acquire verb forms earlier when the lemma, ending, or combination was frequent in the input. Unlike the previous two

analyses, this provides a developmental account of how children could record frequencies related to strings in their input and use that to develop their morphological rules.

4.5 Is the effect of input frequency real?

We have seen different regression analyses report effects of input frequency of inflected forms on verb form AoA. However, as noted in the introduction, these effects are difficult to interpret because estimates of age of acquisition based on naturalistic speech samples are confounded with frequency-based differences in the probability that particular forms will be sampled in children's speech. In a final analysis, we therefore attempt to distinguish between effects of input frequency and sampling effects. To do this, we residualized log input frequency (token frequency of inflected verb forms) against log lemma frequency crossed with log ending frequency, to create a measure of verb form frequency that is independent of lemma and ending frequency. We then built a model that predicted log verb form AoA based on log lemma frequency crossed with log ending frequency plus the residualised log surface frequency. In this model, sampling likelihood will be represented by the main effects and interactions of lemma and ending frequency. The residualised log input frequency provides a measure of the effect of form frequency independent of sampling effects.

The resulting model revealed a significant effect for all four predictors as shown in Table 10. That is to say, the children tended to learn forms with frequent lemmas early (β =-0.060, SE=0.008, F(1,306)=37.304, p<.001), and tended to learn forms with frequent endings early (β =-0.000005, SE=0.000001, F(1,306)=21.116, p<.001). There was also a significant effect of the interaction of these two factors (β =-0.000005, SE=0.000001, F(1,306)=35.561, p<.001). Importantly, however, residualised log input frequency was also a significant predictor of AoA (β =-0.103, SE=0.012, F(1,306)=68.046, p<.001), which suggests that the part of input frequency that was independent of lemma and ending frequency influenced AoA. This model explained 34% of the variance.

Table 10. Model summary for log verb form AoA by log input frequency of the lemma and ending and residualized input frequency of inflected verb forms

	Estimate	Std. Error	F value	P
log input frequency of lemma	-0.060	0.008	37.304	< .001***
input frequency of ending	-0.000005	0.000001	21.116	< .001 ***

log input frequency of lemma : input frequency of ending	-0.000005	0.000001	35.561	< .001 ***
residualized input frequency of inflected verb form	-0.103	0.012	68.046	< .001 ***

One goal of this last analysis is to deal with the possibility that the relationship of AoA and input frequency is just due to sampling effects. This analysis found that frequent lemmas tend to have earlier AoAs and frequent endings have earlier AoAs, and these effects could be due to sampling. But we also found an effect for residualized surface frequency measure, which is the part of the surface frequency which cannot be explained by the lemma and ending frequency. The fact that this predictor also predicted AoA argues that surface input frequency has an effect beyond those due to sampling effects.

This analysis also addresses the compositionality of morphology. If speakers only store lemmas and endings, and then combine them with a rule/pattern, then there will be no storage of surface forms and surface form frequency will not significantly

predict when forms are learned. But we found that residualized surface form frequency does predict AoA, which suggests that speakers are storing and strengthening surface forms based on their frequency. Thus, this analysis also suggests that non-compositional representations are being stored.

Finally, this last analysis represents a best guess as to how children are encoding input frequency information in Japanese morphology. The morphological complexity and ending identity models explain a large amount of variance (R^2=.35 and .52 respectively) and this demonstrates that children are not simply working with unsegmented whole forms. But as we discussed earlier, these models make inappropriate assumptions about the information that is used for predicting AoA. Children are given input sentences which provide frequency information about how lemmas, endings, and surface forms are used by others. The last model explains the most variance in AoA using variables that approximate the kinds of information that children can access.

5. Discussion

The aim of the present study was to investigate the order and age of acquisition of Japanese verb morphology through a series of descriptive, correlational and regression analyses. In a first set of analyses, we used type-based criteria and examined the order of emergence of endings in the three earliest child corpora in order

to establish which are the earliest endings to emerge in Japanese-speaking children's output and how consistent is the pattern of emergence across children. The descriptive and correlational analyses showed that, although the identity of the earliest endings to emerge was relatively consistent, there was no invariant order of emergence across children. It also showed that all of the productivity measures generated age of acquisition measures that were negatively related to the token frequency of the relevant ending in the children's speech, and were hence difficult to interpret. These results suggest that using type-based criteria may not be the best approach to understanding age of acquisition.

In a second set of analyses, we took a probabilistic perspective, and explored the factors that influence age of acquisition of inflected verb forms in a dataset combined across children. Our regression analyses showed that age of acquisition was related to ending identity and this model explained the most variance of any model. Furthermore, we found that the frequency of verb lemmas and endings, as well as their interaction, were useful in predicting age of acquisition. In this Japanese data set, type and token frequency of endings are essentially the same and this suggests that the difficulty of using type-based criteria to predict order of emergence in the first set of analyses (Study 1) was not due the absence of any effect of type frequency. Rather the productivity measures that are traditionally used are coarse measures (first 10 endings that were productive with 10 lemmas) and the rank order within particular children may

be sensitive to sampling and child-specific variability. In addition, since the effect of ending type/token frequency interacted with lemma token frequency, traditional approaches that do not incorporate lemma frequency or its interaction may not exhibit the effects that were found here. Our results suggest that the question about whether ending type frequency is important in language acquisition may be more profitably examined by using a regression-based approach.

Regarding morphological complexity, our results count against the general assumption in the field that simple forms are acquired earlier than complex forms (Anglin, 1993; Takanashi, 2009; Iwatate, 1981). Instead, complex forms can be acquired earlier than simple forms, at least where complexity is measured in terms of the number of morphemes added to the lemma. This effect only occurs when input frequency is factored out simultaneously, which might highlight the additional meaning associated with these terms. We argued that these complex forms have strong emotional valence, which means that children tend to pay more attention to each instance of these forms and therefore learn them earlier than would be expected on the basis of their input frequency. The emotional force of these forms might also contribute to their usage, which might help increase the likelihood that they reach the inclusion criterion in our study. Hence, there are several factors that might explain the earlier acquisition of complex forms in our corpus.

One set of mechanisms that can explain why forms with multi-morphemic endings are acquired earlier are error-based language acquisition models that do next word prediction (Twomey, Chang & Ambridge, 2014; Fitz & Chang, 2017; Chang, 2009). These models learn by using prediction error which is defined as the difference between the expected next word and the actual next word. For example, if a cup is broken, then the child might predict the verb *kowareta* (break-PAST). But if the child hears *kowarechatta* (break-COMPLETIVE-PAST, with the COMPLETIVE marking a subjective negative stance on the event), their expectation turns out to be wrong and prediction error is generated. This error is used to change the model's language representations, so the model will learn more from hearing *kowarechatta* than from the more expected *kowareta*. Since verbs with single-morpheme endings are frequent and can often be used in place of verbs with multi-morphemic endings, listeners are likely to expect the shorter forms and when they hear forms with multi-morphemic endings, they will generate more error and show greater learning than would be expected on the basis of the input frequency of those words. In error-based models with hidden layers, this error can cause deeper changes to the hidden representations, which might explain why these terms come to have emotional meanings not present in the single morphemic forms.

The importance of semantics was also tested with respect to the identity of endings. Our comparison of different regression models suggests that AoA is not fully

explained by ending frequency and seems to be more dependent on the categorical distinctions that the different endings encode. This implies that children are more sensitive to some semantic distinctions than others and that this also plays a role in determining AoA.

The last regression model investigated whether it was possible to establish a relation between the age of acquisition of particular inflected verb forms and the frequency with which those forms occur in the input, even after controlling for sampling effects in naturalistic speech. It revealed an effect of form frequency in the input on age of acquisition even after controlling for lemma frequency and ending frequency. This finding suggests that the input frequency effects revealed in the second part of the study cannot be explained away as sampling effects.

Perhaps the most distinctive feature of the present study is the use of a large combined dataset and probabilistic measures of AoA in the statistical analyses. Our regression analyses combined seven Japanese corpora in CHILDES into a single large corpus that provided a much larger sample than previous studies. Furthermore, we analysed a large set of forms (311 verb forms) and used age measurements based on the first 30 instances which helps to make the results of the study less dependent on the particular conversations that happened to occur within particular recording sessions and increases the representativeness of the results. Since we do not have rich enough input to fully characterise the input frequency or usage of particular children, it makes sense

to use these aggregated corpora and measures to characterise the typical patterns in the acquisition of the language.

The findings of the study also have a number of further implications for the field. First, they point the difficulty of using frequency sensitive measures to study language acquisition, because these measures are sensitive to sampling effects. In the type-based analysis, we saw that endings that were frequent in the input reached productivity earlier. In the exploratory analysis, verb form AoA was also sensitive to the likelihood of lemmas and endings in the input. The implication is that, if we are interested in understanding language acquisition, we need to use techniques that can factor out sampling biases such as our use of residualized surface frequency. This is likely to be particularly challenging in languages like Japanese, in which it is much more difficult to identify obligatory contexts than it is in English.

Second, our findings illustrate the value of adopting a more exploratory approach to the question of morphological productivity in which regression analyses are used to investigate the factors that affect the age at which particular forms appear in children's speech. This approach has the advantage that it allows the researcher to remain agnostic about whether children's use of particular inflections is or is not fully compositional and productive and hence to differentiate between cases where the patterning of the data does provide strong evidence that the child's knowledge is compositional and productive and cases where it does not. This is likely to be

particularly important in agglutinative languages like Japanese, where the researcher not only has to identify whether the child's use of a particular inflected verb form is productive, but also the level at which it is productive. For example, does a child who can use two-morpheme endings such as COMPLETIVE-PAST productively represent these endings as one unit or as two units? One implication of our results is that the level at which children's verb forms are represented may vary, with some forms being learned as unanalysed units, others being productive at the level of lemma and ending, and others being productive at the level of each individual morpheme, with this depending on the distribution of relevant forms in the input.

Third, our findings suggest that, where frequency in the input does predict the age at which particular inflected verb forms appear in children's speech, these effects cannot be simply explained away as sampling artefacts. It is perhaps important to note at this point that the controls employed in the present study do not completely rule out a sampling effect explanation, since they do not rule out the possibility that what is driving any effect is the likelihood that a particular inflected verb form (i.e. a particular combination of lemma and ending) will occur in both the child and the caregiver's speech (as opposed to the combined likelihood that a particular lemma and a particular ending will occur). However, by controlling for effects of lemma and ending frequency, they do rule out two of the more obvious confounds in previous research. Thus, they

provide stronger evidence for effects of form frequency in the input than many previous studies.

To conclude, the present corpus-based study of Japanese provides evidence against the validity of traditional measures of productivity and shows how a more probabilistic approach to the issue of morphological productivity can generate important insights into the way in which agglutinative morphology is acquired. These findings challenge the idea that children's inflectional knowledge becomes fully productive at some early point in development, and are consistent with the constructivist claim that the development of morphological productivity is a gradual process (e.g., Aguado-Orea & Pine, 2015; Dąbrowska, 2008 Tomasello, 2003). At the same time, they also underline the need for more in-depth study of how young children's varying sensitivity to different elements of complex verb forms is related to their developing morphological knowledge.

References

Aguado-Orea, J. & Pine, J. M. (2015). Comparing different models of the development of verb inflection in early child Spanish. PloS One, 10(3), e0119613.

Aksu-Koç, A., & Slobin, D. I. (1985). The acquisition of Turkish. In D. I. Slobin (Ed.), The crosslinguistic study of language acquisition, Vol. 1. (pp. 839-878). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ambridge, B., Rowland, C. F., Theakston, A. L. & Kidd, E. J. (2015). The ubiquity of frequency effects in first language acquisition. Journal of Child Language, 42, 239-273.

Anglin, J. M. (1993). Vocabulary development: A morphological analysis. Monographs of the society for research in child development, 58(10, Serial No. 238)

Bassano, D. (2000). Early development of nouns and verbs in French: Exploring the interface between lexicon and grammar. Journal of Child Language, 27(3), 521-559.

Berko, J. (1958). The child's learning of English morphology. Word, 14(2-3), 150-177.

Brown, R. (1973). A first language: the early stages. Cambridge, MA: Harvard University Press.

Brown, P. (1998). Children's first verbs in Tzeltal: Evidence for an early verb category. Linguistics, 36, 713–53.

Bybee, J. L. (1985). Morphology: A study of the relation between meaning and form (Volume 9). John Benjamins Publishing.

Bybee, J. L. (1995). Regular morphology and the lexicon. Language and Cognitive Processes, 10(5), 425-455.

Cazden, C. B. (1968). The acquisition of noun and verb inflections. Child Development, 39, 433-448.

Chang, F. (2009). Learning to order words: A connectionist model of heavy NP shift and accessibility effects in Japanese and English. Journal of Memory and Language, 61, 374-397.

Chang, F. (2017). The LuCiD language researcher's toolkit [Computer software]. Retrieved on Dec 5th, 2018 from http://www.lucid.ac.uk/resources/for-researchers/toolkit/

Choi, S. (1991). Early acquisition of epistemic meanings in Korean: A study of sentence-ending suffixes in the spontaneous speech of three children. First Language, 11, 93–119.

Clancy, P. (1985). The acquisition of Japanese. In D. I. Slobin (Ed.), The crosslinguistic study of language acquisition, Vol. 1. (pp. 373-524). Hillsdale, NJ: Lawrence Erlbaum Associates.

Clark, E. V., Hecht, B. F., & Mulford, R. C. (1986). Coining complex compounds in English: Affixes and word order in acquisition. Linguistics, 24(1), 7-30.

Dąbrowska, E. (2008). The effects of frequency and neighbourhood density on adult speakers' productivity with Polish case inflections: An empirical test of usage-based approaches to morphology. Journal of Memory and Language, 58(4), 931-951.

de Villiers, J. G., & de Villiers, P. A. (1973). A cross-sectional study of the acquisition of grammatical morphemes in child speech. Journal of Psycholinguistic Research, 2(3), 267-278.

Dressler, W. U. (2005). Morphological typology and first language acquisition: Some mutual challenges. In G. Booij, E. Guevara, A. Ralli, S. Sgroi & S. Scalise (Eds.), Morphology and Linguistic Typology: Online Proceedings of the Fourth Mediterranean Morphology Meeting. (pp. 7–20). Bologna: Università degli studi di Bologna.

Dressler, W. U. (2010). A typological approach to first language acquisition. In Kail, M. & Hickmann, M. (Eds.). Language acquisition across linguistic and cognitive systems, 52, 109-124.

Fernández Martínez, A. (1994). El aprendizaje de los morfemas verbales: Datos de un estudio longitudinal. In S. López Ornat, A. Fernández, P. Gallo, & S. Mariscal (Eds.), La adquisición de la lengua española (pp.29–46). Madrid: Siglo XXI de España Editores.

Fitz, H., & Chang, F. (2017). Meaningful questions: The acquisition of auxiliary inversion in a connectionist model of sentence production. Cognition, 166, 225-250.

Gathercole, V. C. M., Sebastián, E., & Soto, P. (1999). The early acquisition of Spanish verbal morphology: Across-the-board or piecemeal knowledge? International Journal of Bilingualism, 3 (2-3), 133-182.

Gries, S. T. (forthcoming). Analyzing dispersion. In Magali Paquot & Stefan Th. Gries (eds.). *Practical handbook of corpus linguistics*. Berlin & New York: Springer.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. Developmental Psychology, 27(2), 236.

Iwatate, S. (1981). Iti nihongo ji no doosikei no hattatu ni tuite. Annual Report of Faculty of Letters of Gakushuin University, 27, 191-205.

James, S. L., & Khan, L. M. (1982). Grammatical morpheme acquisition: An approximately invariant order? Journal of Psycholinguistic Research, 11(4), 381-388.

Kato, S., Sato, Y., Chikuda, Y., Miyoshi, R., Sakai, Y. & Koizumi, M. (2003). “Root infinitives”: Nihongo karano kensho [“Root infinitives”: From the perspective

of Japanese]. Tohoku University Linguistics Journal, 12, 113-127. Sendai: Tohoku University.

MacWhinney, B. (1978). The acquisition of morphophonology. Monographs of the Society for Research in Child Development, 43(1), 1-123.

MacWhinney, B. (2000). The CHILDES project: Tools for analyzing talk. Third Edition. Mahwah, Lawrence Erlbaum.

Matthews, D. E., & Theakston, A. L. (2006). Errors of omission in English-speaking children's production of plurals and the past tense: The effects of frequency, phonology, and competition. Cognitive Science, 30(6), 1027-1052.

Mithun, M. (1989). The acquisition of polysynthesis. Journal of Child Language, 16(2), 285-312.

Miyata, S. (2004a). Japanese – Miyata – Aki Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-055-3

Miyata, S. (2004b). Japanese – Miyata – Ryo Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-056-1

Miyata, S. (2004c). Japanese – Miyata – Tai Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-057-X

Miyata, S. & Nisisawa, H. Y. (2009). Japanese – MiiPro – Asato Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-474-5.

Miyata, S. & Nisisawa, H. Y. (2010). Japanese – MiiPro – Tomito Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-472-9.

Naigles, L. R. & Hoff-Ginsberg, E. (1998). Why are some verbs learned before other verbs? Effects of input frequency and structure on children's early verb use. Journal of Child Language, 25, 95-120.

Nisisawa, H. Y. & Miyata, S. (2009). Japanese – MiiPro – Nanami Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-473-7.

Nisisawa, H. Y. & Miyata, S. (2010). Japanese – MiiPro – ArikaM Corpus. Pittsburgh, PA: TalkBank. ISBN 1-59642-475-3.

Ono, T., & Suzuki, R. (1992, August). The development of a marker of speaker's attitude: The pragmatic use of the Japanese grammaticized verb shimau in conversation. In Annual Meeting of the Berkeley Linguistics Society (Vol. 18, No. 1, pp. 204-213).

Otomo, K., Miyata, S. & Shirai, Y. (2015). The Acquisition of Verb Morphology in Japanese: Order of Acquisition and Relationships with Maternal Language Input. The Japanese Journal of Developmental Psychology, 26(3), 197-209.

Peters, A. M., & Menn, L. (1993). False starts and filler syllables: Ways to learn grammatical morphemes. Language, 69(4), 742-777.

Pinker, S. (1984). Language Learnability and Language Development. Cambridge, MA: Harvard University Press.

Pizzuto, E., & Caselli, M. C. (1992). The acquisition of Italian morphology: implications for models of language development. Journal of Child Language, 19, 491-557.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Räsänen, S. H., Ambridge, B., & Pine, J. M. (2014). Infinitives or bare stems? Are English-speaking children defaulting to the highest-frequency form? Journal of Child Language, 41(4), 756-779.

Rowland, C. F., Pine, J. M., Lieven, E. V. M. & Theakston, A. L. (2003). Determinants of acquisition order in wh-questions: Re-evaluating the role of caregiver speech. Journal of Child Language, 30, 609-636.

Shibatani, M. (1990). The languages of Japan. Cambridge University Press.

Shirai, Y., & Andersen, R. W. (1995). The acquisition of tense-aspect morphology: A prototype account. Language, 71, 743-762.

Slobin, D. I. (1985). The crosslinguistic study of language acquisition, Vol. 2. Hillsdale NJ: Erlbaum.

Stoll, S., Bickel, B., Lieven, E., Paudyal, N. P., Banjade, G., Bhatta, T. N., Gaenszle, M., Pettigrew, J.,Rai, I. P., Rai., M., Rai, N. K. (2012). Nouns and verbs in Chintang: Children's usage and surrounding adult speech. *Journal of Child Language*, *39*(2), 284-321.

Suzuki, R. 1999. Language socialization through morphology: the affective suffix -chau in Japanese. Journal of Pragmatics, 31, 1423–1441.

Takanashi, M. (2009). Nihongo doosikee no shuutoku junjo: Siyoo ikyo apurooti (usage-based approach) no kanten kara. Language and information sciences, 7, 33-50.

Tanoue, E. K. (1981) Language development in two Japanese-speaking children: A cross-linguistic study. Unpulished qualifying paper, teacher's College, Columbia University.

Tatsumi, T., Ambridge, B., & Pine, J. M. (2018). Disentangling effects of input frequency and morphophonological complexity on children's acquisition of verb

inflection: An elicited production study of Japanese. Cognitive Science, 42, 555-577.

Theakston, A. L., Lieven, E. V., Pine, J. M. & Rowland, C. F. (2004). Semantic generality, input frequency and the acquisition of syntax. Journal of Child Language, 31, 61-99.

Tomasello, M. (2000). The item-based nature of children's early syntactic development. Trends in Cognitive Sciences, 4(4), 156-163.

Tomasello, M. (2003). Constructing a Language: A Usage-Based Theory of Language Acquisition. Cambridge, MA: Harvard University Press.

Tomasello, M., & Stahl, D. (2004). Sampling children's spontaneous speech: how much is enough? Journal of Child Language, 31(1), 101-122.

Twomey, K. E., Chang, F., & Ambridge, B. (2014). Do as I say, not as I do: A lexical distributional account of English locative verb class acquisition. Cognitive Psychology, 73, 41-71.

Wexler, K. (1994). Optional infinitives, head movement and the economy of derivation in child grammar. In Hornstein, N. & Lightfoot, D. (Eds.), Verb movement, (pp. 305-350), Cambridge, England: Cambridge University Press.

Wexler, K. (1998). Very early parameter setting and the unique checking constraint: A new explanation of the optional infinitive stage. Lingua, 106, 23-79.

Yang, C. (2013). Ontogeny and phylogeny of language. Proceedings of the National Academy of Sciences, 110(16), 6324-6327.

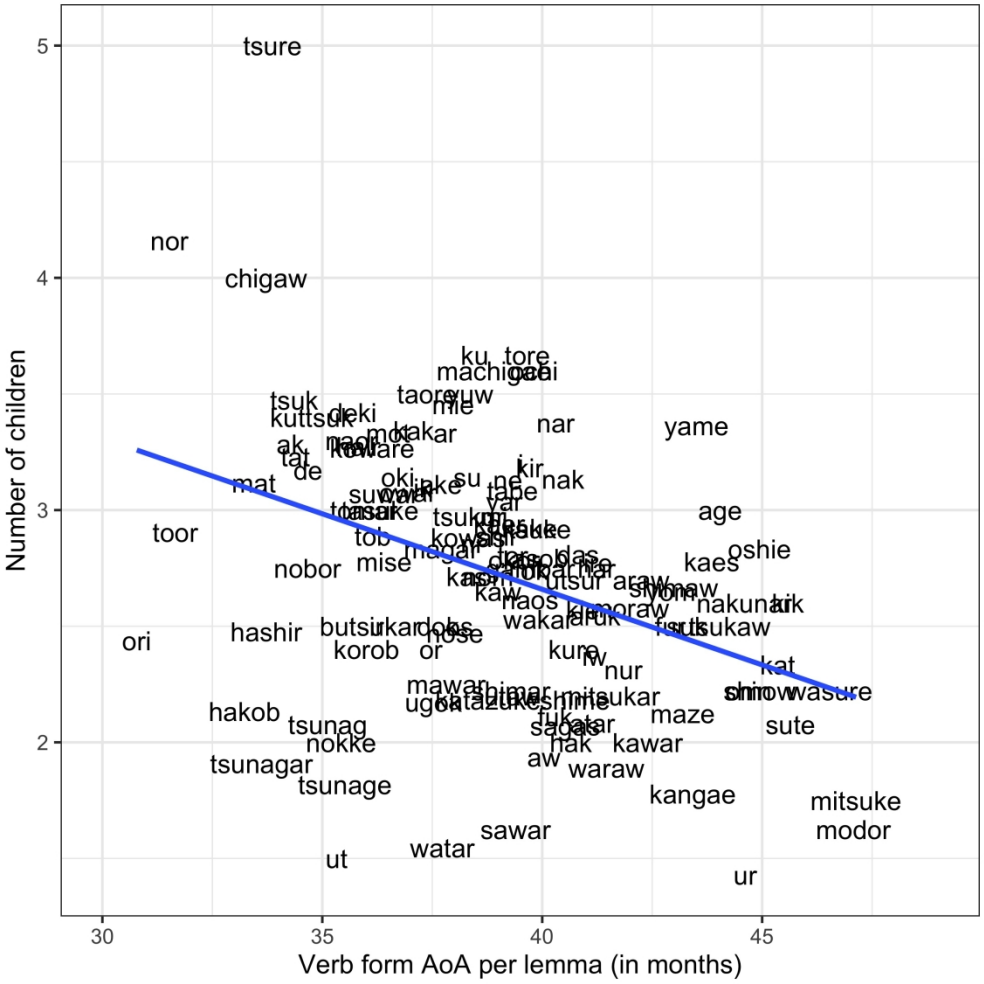

Figure 1. Number of children that were sampled for calculating verb form AoA by lemma

1023x1023mm (72 x 72 DPI)

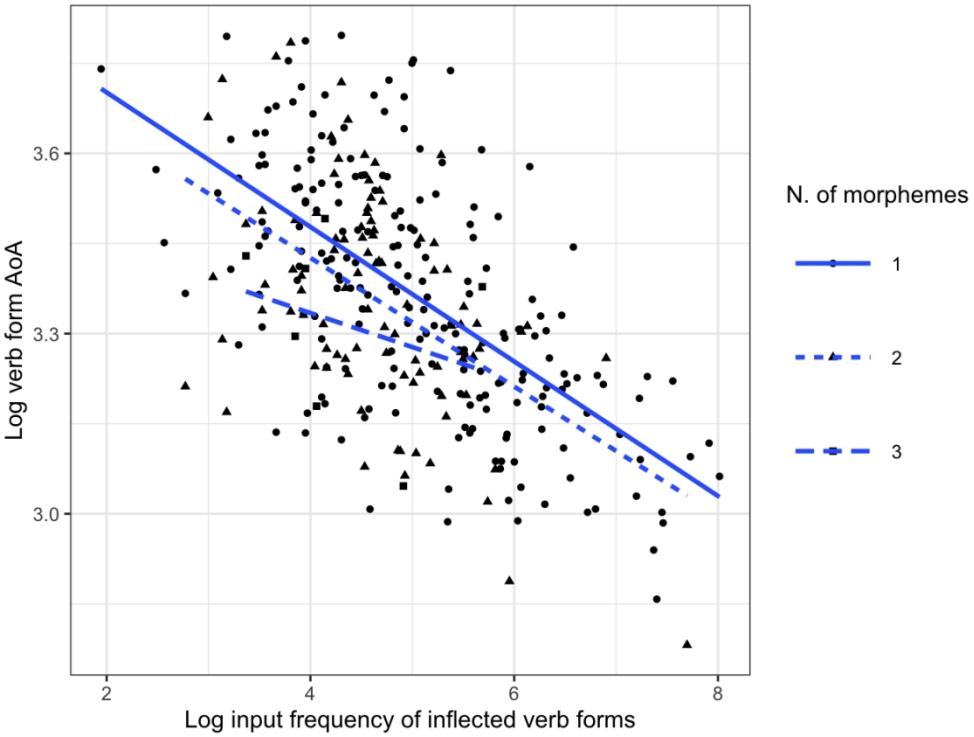

Figure 2. Log verb form AoA by log input frequency of inflected verb forms and morphological complexity (number of morphemes in the ending)

451x338mm (72 x 72 DPI)

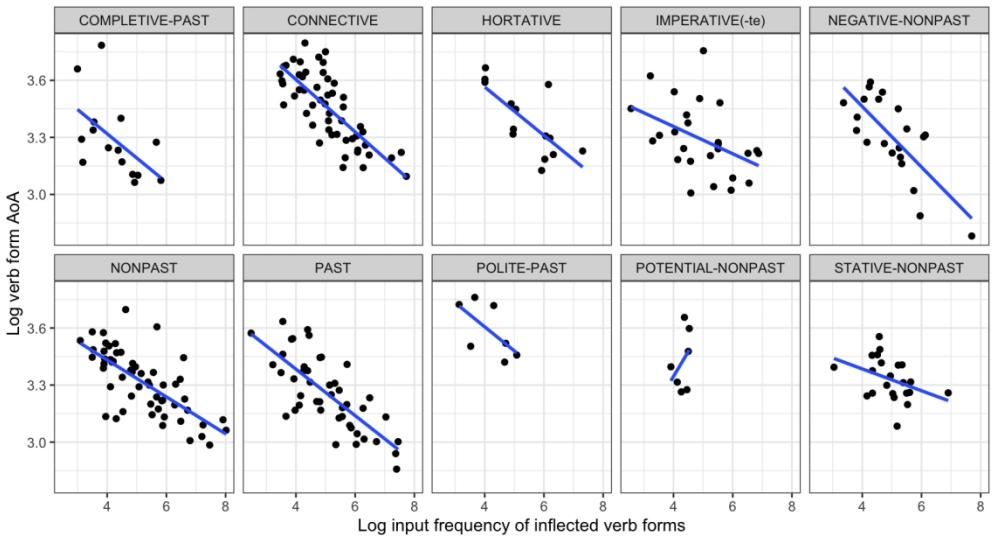

Figure 3. Log verb form AoA by log input frequency of inflected verb forms and ending categories

620x338mm (72 x 72 DPI)